Endless Runway- Orientation, Design and Calculations

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***Abstract* — The concept Endless Runway is not new, in the mid of 19th century the test were done by US navy and General motors. but now when the air trafficking is rising too fast and problems are spreading their arm towards land actuation for fulfillment of more runways and deforestation taking place, the circular runway again striking in designer's mind. Circular runway is the one of best way to resolve air traffic and also provide a safe landing and take-off operations at any conditions. In the case of Circular runway the chances of accidents also will be low and multi operations can be resolve at a several time. In a age when we are expecting 60 million passengers per day it is very clear that the chances of accidents also will be higher and air traffic will increase and more land will require for airport and runway terminals. So the idea of Circular runway is very initiative where we can design the all require buildings inside the circular track.**

***Keywords*— ICAO, FAA, Air Traffic, Airport Capacity etc.**

I. INTRODUCTION

The 'Circular Runway' project is a revolutionary change in the Airport history .It is an innovative concept for airport operations in long term future .This concept of endless airport enables multiple take-off and landing simultaneously increasing the airport capacity. It is a concept which consists of an airport with one circular circumventing runway .The airport terminals with all aircraft ,passenger, baggage ad other facilities are located inside the circular runway only, so that passenger fast transfer times and small taxiing distances can be achieved.

The uniqueness of the circular runway is that it can be used in any wind direction through the possibility for an aircraft to operate always with headwind during take-off and landing.

There are three different situations that occurs while aircraft landing on circular runway.

a) In strong wind conditions, the aircraft will fly in sequence towards endless runway to allow for landing at touchdown point, where dependency from the wind is at a minimum (at exactly headwind).

b) In low wind conditions, aircraft can land towards any direction .This enables possibility for shorter landing intervals.

c) With changing wind, the aircraft can gradually move with wind direction .No break in the sequence will occur as it can occur with conventional runway configuration.

Figure 1 Overview of circular runway

II. OBJECTIVE

When we plan an airport, all type of aircraft's landing and take-off operations take place including bigger and smaller aircraft. In case of circular runway we can't classify the runway for particular aircraft. So we designing here considering the design parameters for the largest aircraft BOING 474.

So our main objectives are as under

A) To find out the Radius of circular runway for safe operations.
B) To find the exact bank angle for safe ground rolling.

III. METHODOLOGY

A. Description of Circular Runway

The circular runway is an innovative concept for airport operations in the long term future which is based on a radically new airport design encompassing a circular circumventing runway.

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In order to allow to sufficient number of landing and take-off at a time, the runway inner radius is set to more than 1500 meters. The minimum length for circular runway thus should be 10,000 meters comparable three times more than a straight runways, which is long enough to allow multiple simultaneous landing and take-off on the runway and to build the airport infrastructure inside the circular runway while keeping the airport compact.

Due to higher centrifugal forces for a narrower runway the runway width is set to be 140 meters for avoidance of discomfort of passengers. To limit the effects of centrifugal forces, the outside of runway is banked with increasing angle.

As the aircraft accelerates for take-off, it moves from the flat inner part of runway to towards the other outer banked part until aircraft reaches the lateral position on the runway where the bank angle is fits its lift-off speed. The same applies during landing operations.

B. Take-off and Landing Live trials on Circular Runway

In 1938 the first circular runway take off was demonstrated by a stunt man in Riverdale airfield, Maryland. The aircraft was set with a hub, a spindle, and a release gear.

The circular runways were also used during Second World War for training purposes to practice cross wind, back wind landings. On the other hand, it was also possible to avoid crosswind by using an appropriate runway segment. These airports were not circular, but rather consisted of straight runways laid out in a pattern where the end of one runway would connect with the next runway at about a 45 degrees angle.

Circular flat take-off was first tested with a lighter aircraft in 21st of March 1955 on Lake Kegonsa which was converted in ice in Wisconsin Europe.

C. Human factors,

a) Pilots

The first feeling of pilots when they were landing was that as they are “flying into a hole” but after some landing when they were habitual the impression was disappeared. This impression was due to particular shape of circular track which was much narrower and more steeply curved in cross section than theoretical ideal of circular runway. According to them it was much harder to keep the aircraft banked on ground as they experienced a tendency to level the wings on straight runway, due to lower bank angle of aircraft in compare with bank angle of track caused the slight drift outside of the track of aircraft. When the pilots made their first landings, they tended to touch down first with one wheel and then the other, which could be quite dangerous on a conventional straight runway. They realized it when watching the movies of the flights, since they did not feel it at all during the landings. Indeed, the circular runway tended to correct smoothly pilots errors.

After regular trials, pilots mastered the knack and they stated an exceptional lateral stability now the aircraft were finding easily its natural line corresponding to its speed on circular track. Now the cross wind was no more a factor , margins for errors like degree of banked angle, cross section, speed of landing, point of touchdown was not so critical as the runway tended to correct them. So with all this different shared experienced of different pilots, the safety of circular runway was proved of circular runway.

b) Passenger

i) In flight

A stress is occurred in structure due to any force which working from outside to deflect its flight from its straight line. The amount of this force is the load factor. Loading conditions due to gusts, landing, and manoeuver. In aerodynamics, the load factor is the ratio of the apparent weight created by the acceleration to the gross weight of the aircraft created by gravity. It is measured in g, the acceleration of gravity ($g \approx 9,81$ m·s-2).

- Due to the low climb and descent slopes the load factor is always equal to 1 during climb and descent. In a constant turn, the acceleration consecutive to the modification of the trajectory corresponds by thrust and is not represented in the following diagram.

This diagram was taken from pilots hand book where load factor during a turn is explained.

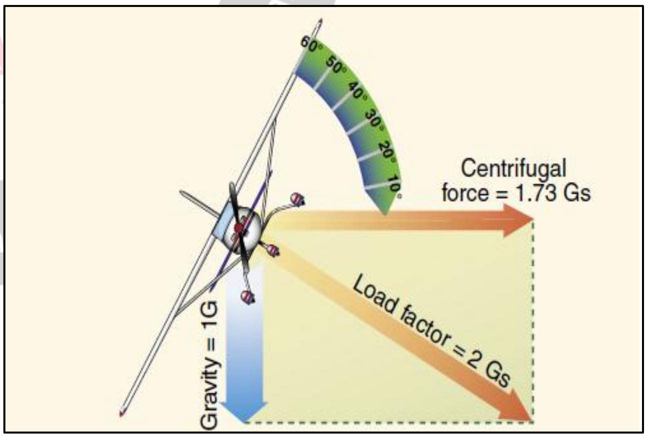

Fig 2 Load factor diagram

ii) On ground

The lateral accelarations feel on ground in aircraft are almost similar to lateral accelaration of trains. As we know the accelarations set for trains in the way so that the passengers do not sustain a lateral accelaration more than 1.2 m/s^2, which correspond to 0.23 g.

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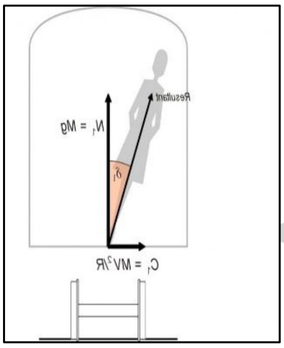

Fig 3 Lateral acceleration on ground

D. **Runway Length**

Runway length for the circular airport will be almost greater more than three times of normal runway. The length of runway depend upon the critical aircraft, that is to say most demanding aircraft in terms of take-off performance.

Aircraft manufacturer provide for each aircraft a take-off distance for non-standard conditions. We must look on that published performance to establish an optimum runway length. (Runway + stop way + clear way)

E. **Design Considerations**

- Length of circular runway
- Radius of circular runway
- Width of runway
- Bank angle
- Elevation
- Sight distance

Design Constraints as per ICAO and FAA

1) Design Speed;- An aircraft of larger size need minimum 285-290 km per hour, and smaller 155-160 km per hour.

2) Radius:- An aircraft need minimum radius of 180 m for turning.

3) Width;- Width of runway varies from 55 m to 80 for small and bigger size of airport respectively.

4) Bank Angle;- The minimum bank angle for aircraft is 6 degree and maximum recommended by ICAO is 60 degree at which in case of emergency a craft can work.

5) Elevation;- Elevation of runway should be such that the wings of craft should not be in touch with ground, minimum clearance should be 0.73m and maximum should be 5.3m .

6) Sight Distance;- Sight distance for pilot recommended is 500 m to 950 m. some time sight distance not obtain in that case pilot done operations with the help of central marking line.

Table 1 Current Atmosphere of Jewar area

Altitude	201 m
Temperature	40^{o}
Friction	0.35
Wind speed	6kmph-75kmph
Rain condition	7.5 cm

F. **CALCULATIONS-**

LENGTH OF RUNWAY-using the formula of altitude as,

Length of circular runway is considered, keeping the point

- The critical aircraft, that is to say the most demanding aircraft in terms of take-off performance.
- The most demanding environmental conditions during runway use, such as the mean daily temperature for the hottest month of the year at the airport.
- The obstacles that the aircraft needs to overfly with a 35 feet vertical margin

Aircraft manufacturers provide for each aircraft a take-off run , a take-off distance and a landing distance for non-standard conditions. We must look at those published performances to establish an optimal runway distance (runway + stopway + clearway).

Since the distances are given on the standard condition of temperature which is 15°C, pressure (sea level), slope (null), a dry runway and in absence of wind, some correction factors need to be applied.

After the all correction provided by ICAO and FAA, we also may correct the length

$Fa=1+0.07a/300$

$Ft=1+0.01(tr-tsh)$

$FS=1+0.1s$

Where;

Fa = correction in altitude

Ft = correction as a function of temperature

Fs = correction as a function of slope

a = altitude

tr = reference temperature

tsh = corresponding standard atmosphere to every altitude

s = slope

Value of equation $Fa\times Fs\times Ft$ should be greater than 1.35.

IV. CALCULATION

As we know

Altitude of greater Noida of Jewar airport (a) = 201

Reference temperature of Land Area = 40 ^{0}C

Standard atmosphere to every altitude by FAA = 25^{0}C

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Slope(max) of runway by recommended by ICAO = 0.07

Now from equation (A) (B) & (C) we have,

Correction as a function of slope F_s = 1+ s = 1+0.07

F_S = 1.07

Correction in Altitude F_a = 1+ 0.07*a

F_a = 1.0469

Correction as a function of temperature = 1+ 0.01 ($t_r - t_{sh}$)

f_t = 1.15

From the equation 5, 6 & 7 we have the value of equation,

$Fa \times Fs \times Ft$ = 1.07 × 1.0469 × 1.15

= 1.67

Design criteria

According to ICAO and FAA the value of multiplication of temperature, altitude and slope correction should be greater than the value 1.35, and the design value is 1.67. So our design is safe.

RADIUS-

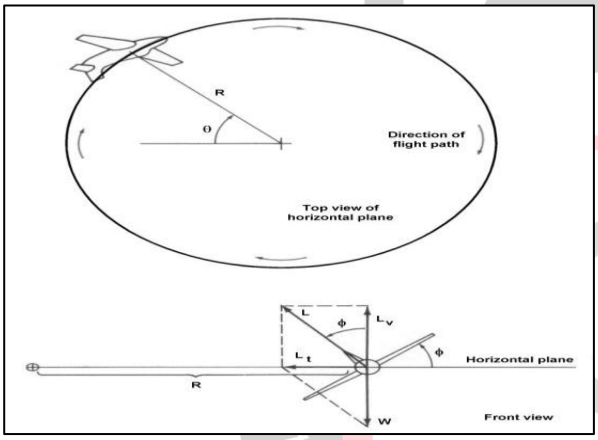

Figure 4 Radius of circular runway

Radius of runway should be such that the landing and taking-off operations should be done without any extra effort. So designing for the biggest aircraft boing 474, which need maximum speed for landing and take-off as 250 kmph.

$$R = \frac{V2}{125F}$$

v= 250 kmph

f= 0.35

so R= 62500/43.75

R= 1428.57 m ~1450 m

ELEVATION OF RUNWAY

Elevation on circular runway is very necessaary because of risk of skit of back gear of aircrat due to its high speed and slight turn. But the necessary elevation on circular runway track should be considering the comfort level of passengers.

When a plane will land or take-off on a circular runway due to its necessary high speed palne will face a centrifugal force which will try to deviate the plane, so the skiting or sliding will take place 0n back gear. To counter act this centrifugal force necessary elevation we are providing on track.

The total centrifugal force F_c,

$$\mathbf{F_c = mV^2/R}$$

Mass (m) = 362870 kg

Speed (v) = 250 kmph

Radius (R) = 1450 m

Values of mass and speed are taken for boing 474.

$$\mathbf{F_c = WV^2/Gr}$$

$= 362870*(69.4)^2/9.81*1450$

= 122.6 KN

So to reducing the effect of this force on plane we are providing necessary elevation using the formulae recommended by ICAO and FAA both,

$$\mathbf{e+f = V^2/125R}$$

f= friction of pavement

V= speed

R= radius

e= required elevation

- According to FAA and ICAO the friction between tire and pavement should be between 0.35-0.45
- For the circular track of JEWAR airport we consider the friction value 0.35.

Now the value of elevation,

$$\mathbf{e = V^2/125\,R - f}$$

= [250x250 / 125 x 1450] - 0.35

= 14.5 m

A. BANK ANGLE

When we will land flight on the circular elevated curved track, the necessary rolling angle of flight to ground is very major point. The exact rolling angle at every landing and take-off can only be control providing bank angle. The condition for bank angle should be such that the wings of plane should be in touch with the elevated ground of runway track for this the calculation of bank angle should be very exact and accurate.

The recommendation of ICAO for clearance of wing from ground for different aircraft are mentioned below. Considering the minimum clearance from ground we made calculations using the formula of elevation and bank angle.

Table is as follows,

Aircraft type	Aircraft description	ICAO code	Wingtips height
Large	Airbus A380-800	A388	5.3
Mid-sized	Airbus A320-232	A322	3.7
Regional	Saab SF40B	SF34	2.5

Table 2 Height of circular runway

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As we know the formula of bank angle,

= [speed of aircraft / 10] + 7

Where the constant value are used for conversion of units and according to the track behavior regarding frictions. For boing 474 which have the maximum landing and take-off speed 250 kmph or 69.4 m/s.

So bank angle θ= [69.4/10] + 7

= 13. 94 degree

Width of circular runway

Loads transmitted by aircraft are distributed up to 30 m. The excess paved area is used for safety reasons.

The width of a runway shall be not less than the appropriate dimension specified in Table, in meters (for code numbers and code letters definition, refer to Appendix A ([26]).

CODE NO/ CODE LETTER	A	B	C	D	E	F
1	18	18	23	-	-	-
2	23	23	30	-	-	-
3	30	30	30	45	-	-
4	-	-	45	45	60	60

One can see that widths vary from 18, 23, 30, 45 to 60 meters (e.g. necessary for the A380) for a paved runway. For an unpaved one, widths are different, varying from 50 to 80 meters.

Width of the runway is an important factor for *the Endless Runway*. As the aircraft will have to make maneuvers on the runway (make a turn), probably, for safety, the runway needs to be wider than the minimum requirements specified above. As indicated in chapter 2, when using a bank angle, the runway width will also depend on the aircraft's landing speed and even more space needs to be allocated for the runway.

Correction of radius and length width;

As we solve above and calculate the minimum radius of 1450 m, according to length and speed of aircraft tha width of runway we provide of circular track 140 m.

Radius of runway now can examine by the tangent formula also when we have the equation and value of angle.

According to FAA the formula for radius now can ba use

$$R= V^2/ 11.26 \text{ XTANGENT OF ANGLE}$$

Now let assume the tangent angle for the maximum speed of 195 knots. The constant 11.26 is used for the conversion of knots and kmph calculation and feet to meter. Assuming the bank angle 30 degree for each landing and take-off

So $R= (195)^2 / 11.26 \times \tan 30^\circ$

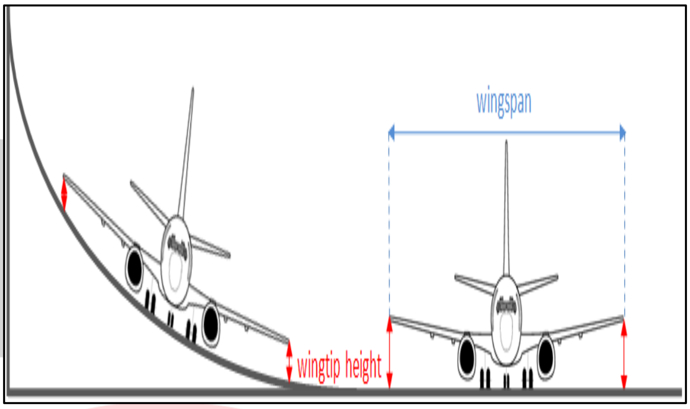
R= 5849.13 FEET

Or R= 1660.88 M

Fig 5 Bank angle of elevated track

V. CONCLUSION

After the estimation and research the following points will present the conclusion of our project.



- We are going to provide circular runway on JEWAR airport for avoiding air traffic.
- The project will reduce the air traffic in future.
- Circular runway is environment friendly project which avoid deforestation and extra land.
- Project is feasible for JEWAR airport.
- In future when expertise are predicting 6 million passenger in jewar, the circular runway will fulfill the demand and several landing at the same time will possible.
- With the radius of 1660 m, including 140 m width of track at a time more than 4 aircraft can land or take-off at the same time.

Runway markings: The markings on the runway help the pilot during the aircraft operations

1. ***Threshold Markings*** Commence 6m from both side of runway ends 2.1m from either side of edge of runway Number of strips=16 Length of each strip=30m Width of strip=1.80m Gap between each strip=1.80m

2. ***Aiming Point Markings*** One rectangular strips on either side of centre line Distance from threshold=300m Length of each strip=50m Width of each strip=10m Gap between strips=20m

3. ***Touchdown Zone Markings*** Number of strip on both side=4 Length of each strip=25m Width of strip=3m Gap between each strip=1.5m Lateral spacing between strips on either side= 20m

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4. ***Centre Line Markings*** Length of each strip=40m Width of strip=0.5m Gap between each strip=35m

5. ***Runway Strip Markings*** 30m from centre line Width = 1m

Runway lightings:

1. Runway End Identification Lights (REIL): Unidirectional (facing approach direction) or unidirectional pair of synchronized flashing lights installed at the runway threshold, one on each side.

2. Runway end lights: Pair of four lights on each side of the runway on precision instrument runways, these lights extends along the full width of the runway. These lights show green when viewed by approaching aircraft and red when seen from the runway.

3. Runway edge lights: White elevated lights that run the length of the runway on either side. On precision instrument runways, the edge-lighting becomes yellow in the last 2,000 ft (610 m) of the runway, or last third of the runway, whichever is less.

4. ***Runway Centreline Lighting System (RCLS):*** The lights embedded into the surface of the runway at 50 ft (15 m) intervals along the runway centreline on some precision instrument runways.

So this is clear from this study that circular runway is revolutionary project for JEWAR airport which will help in future to regulate the air traffic and fulfill the demand of passenger without any delayed.

Fig. 6 Over View Of Circular Runway

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